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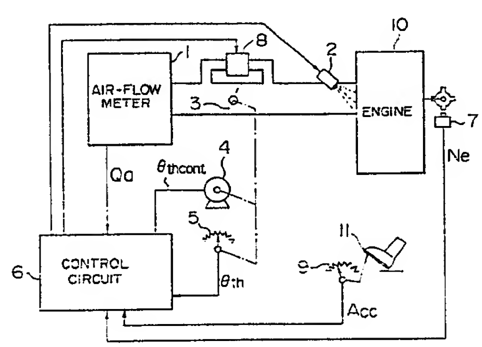
(54) **Fail-safe method and system for automotive engines.**

(57) A fail-safe method and system against sticking of the throttle valve (3) are disclosed for automotive engines of a type with a fuel supply unit (2) and a throttle valve (3) driven through an actuator (4). The amount of depression of the accelerator pedal (11) is detected by an accelerator pedal sensor (9). The system further comprises a device (203) for detecting that the throttle valve (3) is sticked, and a device for controlling the fuel flow rate from the the fuel supply unit (2) in accordance with the output of the accelerator pedal sensor (9) when the throttle valve is sticked. The system preferably further comprises an auxiliary air path bypassing the throttle valve (3). The bypass air amount from the auxiliary air path is controlled if the throttle valve (3) is sticked at a low opening degree, while the fuel flow rate of the fuel supply unit (2) is controlled if the throttle valve (3) is sticked at a middle or high opening degree.

FIG. 1



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Description

FAIL-SAFE METHOD AND SYSTEM FOR AUTOMOTIVE ENGINES

The present invention relates to a fail-safe method and system for automotive internal combustion engines in which a throttle valve for controlling the flow rate of intake air of the engine is driven through an electro-mechanical actuator such as a motor, and particularly to a fail-safe system which becomes effective when the throttle valve of an automotive internal combustion engine has stuck.

Automotive engines are now required to satisfy three major requirements: It must meet the emission gas control regulations and also the requirement of fuel economy, in addition to the required dynamic performances. In automotive engines, whose operating conditions vary over a wide range, fuel flow, ignition timing and etc. are controlled by a computer to satisfy these requirements. Further, an optimum engine control with high accuracy cannot be effected in a satisfactory manner any longer by a conventional system in which the motion of the accelerator pedal directly corresponds to the motion of the throttle valve. In view of this, what is called a drive-by-wire system has been suggested, in which the motion of the accelerator pedal is detected by a sensor, the output of which and various parameters representing driving conditions are used to control an actuator which drives the throttle valve.

A drive mechanism of such a drive-by-wire system comprises a sensor for detecting the amount of depression of the accelerator pedal, a drive circuit for producing a valve drive signal corresponding to the output of the accelerator pedal sensor, and a step motor for opening the throttle valve in accordance with the drive signal. Another system may further include a gear mechanism for transmitting the rotation of the step motor to the throttle valve.

The trottle valve, which directly controls the engine output, is required to have a very high safety. The drive mechanism of the drive-by-wire-system, for its considerably complicated mechanism compared with the conventional system, must be equipped with more safety measures against faults. Especially in the case where the throttle valve sticks while the engine is in operation, the output control of the engine becomes impossible, and therefore it is necessary to provide a fail-safe system against runaway or engine stall.

JP-B-58-25853 discloses a fail-safe system comprising mechanical separation means such as an appropriate clutch between the actuator and the throttle valve, whereby the throttle valve is separated from the actuator by the clutch in the event that the throttle valve has stuck, and the throttle valve is returned to the full-open position by the force of spring.

This prior art system provides satisfactory fail-safe means to the extent that once the throttle-valve has stuck, the engine is brought to idling conditions, and thus the car is prevented from running away. If the engine is fixed to idling state, however, the car cannot drive any longer. This is specifically problematic when the car comes to standstill in an area where it is difficult to seek help or reach a service station.

It is thus desirable that even when the throttle valve has stuck, the engine output can still be controlled so that an emergency operation is possible which allows e.g. to drive to a nearby house or service station for repair.

It is the object of the present invention to provide a fail-safe method and a fail-safe system for internal combustion engines which provide sufficient protection against any case of the throttle valve or the drive mechanism sticking on the one hand, and made it possible that the engine can still be controlled under some restrictions on the other hand, so that the car may continue to be driven safely.

This object is achieved according to claims 1 and 7. The dependent claims relate to preferred embodiments.

In accordance with the conception of the present invention, any case of sticking of the throttle valve is detected, and the bypass air flow and/or the amount of supplied fuel are controlled in correspondence with the opening degree of the throttle valve under sticking condition.

The fail-safe method according to the invention for the operation of internal combustion automotive engines comprising fuel supply means supplying fuel to the engine and a throttle valve provided in the air intake path of the engine and driven by an actuator for controlling the intake air amount of the engine is characterized by

- detecting the amount of depression of the accelerator pedal,
- controlling the throttle valve on the basis of the detected amount of depression of the accelerator pedal,
- detecting of sticking of the throttle valve, and
- in response to the detection of sticking of the throttle valve
- controlling the fuel supply rate from the fuel supply means in accordance with the amount of depression of the accelerator pedal and/or
- controlling the intake air amount via a bypass air amount introduced by means of an auxiliary air path bypassing the throttle valve in accordance with the amount of depression of the accelerator pedal.

According to a preferred embodiment, in response to the detection of sticking of the throttle valve the fuel supply rate is controlled in accordance with the amount of depression of the accelerator pedal if the throttle valve is sticked at a middle or high opening degree, and the bypass air amount is controlled if the throttle valve is sticked at a low opening degree.

According to another preferred embodiment, in response to the detection of sticking of the throttle valve

- an upper engine speed reference value and a lower engine speed reference value corresponding to the amount of depression of the accelerator pedal are set,

- the actual engine rotational speed is detected,
- the reference values are compared with the detected actual engine speed,
- the fuel supply from the fuel supply means is stopped when the actual engine speed is larger than or equal to the upper engine speed reference value and
- the fuel supply means are controlled to supply fuel when the actual engine speed is smaller than or equal to the lower engine speed reference value.

It is preferred to set the engine speed reference values such that the difference therebetween is fixed and proportional to the amount of depression of the accelerator pedal.

According to another preferred embodiment, for engines comprising a fuel injection system the required fuel supply rate is determined on the basis of the output of an air-flow meter, and the fuel injector(s) representing the fuel supply means are controlled in accordance with the required fuel supply rate, and the bypass air amount is controlled by means of a bypass air control valve by changing the duty ratio thereof.

The fail-safe system according to the invention for internal combustion automotive engines in which a throttle valve for controlling the intake air path of the engine is provided which is driven by an actuator is particularly suited for carrying out the above described and comprises
- fuel supply means for supplying fuel to the engine,
- means for detecting the amount of depression of the accelerator pedal,
- signal producing means for producing an output signal for controlling the throttle valve on the basis of the detected amount of depression of the accelerator pedal,
- sticking detection means for detecting that the throttle valve is sticked, and
- fuel supply rate control means for controlling the fuel supply rate from the fuel supply means in accordance with the amount of depression of the accelerator pedal in response to the detection of sticking of the throttle valve.

In accordance with a preferred embodiment, the fail-safe system further comprises means for detecting the opening degree of the throttle valve, said sticking detection means including difference detection means for detecting the difference between the output signal of the signal producing means and the detected opening degree of the throttle valve and producing a signal indicating sticking of the throttle valve when the difference between the amount of said output signal and the detected opening degree of the throttle valve exceeds a predetermined value.

According to another preferred embodiment, the fail-safe system according to the invention further comprises engine speed reference value setting means for setting an upper engine speed reference value and a lower engine speed reference value corresponding to the amount of depression of the accelerator pedal in response to a signal indicating sticking of the throttle valve, means for detecting the actual engine speed, and means for comparing the reference values with the detected actual engine speed and producing the result of comparison, the fuel supply rate control means stopping the fuel supply from the fuel supply means when the result of comparison shows that the actual engine speed is larger than or equal to the upper engine speed reference value and causes the fuel supply means to supply fuel when the actual engine speed is smaller than or equal to the lower engine speed reference value.

In accordance with still another preferred embodiment, the fail-safe system according to the invention further comprises an auxiliary air path bypassing the throttle valve, a bypass air control valve provided therein for controlling the auxiliary air path, means for setting the bypass air amount corresponding to the amount of depression of the accelerator pedal means for comparing the opening degree of the sticked throttle valve with a predetermined throttle valve opening degree reference value in response to a signal indicating the fixing of the throttle valve, and means for controlling the bypass air control valve in accordance with the set value of the bypass air amount setting means when the opening degree of the sticked throttle valve is lower than the throttle valve opening reference value, the fuel supply rate control means controlling the fuel supply means when the opening degree of the sticked throttel valve is higher than the throttle valve opening reference value.

In case the throttle valve is sticking with a high opening degree, then the flow rate of intake air is sufficient, and the flow rate of fuel from a fuel supply such as an injector is controlled in response to the motion of the accelerator pedal. In case the throttle valve is sticking with a low opening degree, in contrast, a sufficient air amount is not obtained, and therefore the intake air pipe including the throttle valve is equipped with a bypass air path and a bypass air control valve for controlling the bypass air flow rate by the bypass air control valve in response to the motion of the accelerator pedal.

In the following, the invention is described with more details with reference to the accompanying drawings.

Fig. 1 is a diagram showing an engine control system to which a fail-safe system according to an embodiment of the present invention is applied.

Fig. 2 shows an internal block diagram of the control circuit in Fig. 1.

Fig. 3 is a flowchart showing the control main routine for the system shown in Fig. 1.

Fig. 4 is a flowchart showing the throttle valve control in the main routine of Fig. 3.

Fig. 5 is a flowchart for fail-safe control in the throttle valve control in Fig. 4.

Fig. 6 is a flowchart for control of bypass air flow rate in the main routine of Fig. 3.

Fig. 7 is a characteristic diagram for explaining the detection of sticking of the throttle valve.

Fig. 8 is a diagram for explaining another case of detecting sticking of the throttle valve.

Fig. 9 is a graph showing the relationship between fuel cut, fuel recovery, engine speed and accelerator pedal signal.

Fig.10 is a graph for explaining the fail-safe

control operation.

Fig.11 is a graph for explaining the way of determining the bypass air flow rate.

The block diagram of Fig. 1 shows an embodiment of an engine control system of fuel injection type to which a fail-safe system according to the present invention is applied. It comprises an intake air flow meter 1, a fuel injector valve 2, a throttle valve 3, an actuator 4 for throttle valve operation, a throttle valve opening degree sensor 5, a control circuit 6, an engine speed sensor 7 detecting the rotational speed of the engine 10, a bypass air control valve 8, and an accelerator pedal sensor 9 connected to the accelerator pedal 11. When the driver steps on the accelerator pedal 11, the amount of depression is detected via the respective angle by the accelerator pedal sensor 9, and a signal Acc is applied to the control circuit 6. The control circuit 6 in turn produces a signal θ_{thcont} for driving the actuator 4 by an amount corresponding to the signal Acc and various parameters indicative of the driving conditions (for example, coolant temperature), with the result that the throttle valve 3 is opened to a degree corresponding to the amount of depression of the accelerator pedal 11.

The control circuit 6 includes a processing control unit such as a microcomputer with a memory unit for controlling the engine 10 by means of a control program stored in the memory unit. When the engine 10 is started and enters a running condition, the intake air flow rate Qa, the engine speed Ne and the opening degree θ_{th} of throttle valve 3 are supplied from the intake air flow meter 1, the engine speed sensor 7 and the throttle valve opening degree sensor 5, respectively. These data are processed thereby to determine the injection pulse timing and the injection pulse duration, thus controlling the flow rate from the fuel injector valve 2. This fuel control system represents a well-known control technique which can be realized in various types. The present invention is not limited to any specific type of fuel control system. In idle state, in order to prevent fall of the idle engine speed under connection of a load (such as an air conditioner, heater, cooling fan or lighting equipment), the open time of the bypass air control valve 8 is controlled by the control circuit 6 in accordance with an idle control program.

A specific circuit configuration of the control circuit 6 is shown in Fig. 2. The CPU 20 is a well-known microprocessor for controlling the whole control circuit 6 and has arithmetic processing functions. A program for determining the fuel injection timing and supply rate or a control program for a fail-safe system according to the present invention is stored in a read-only memory (ROM) 21. The circuit further comprises a random access memory (RAM) 22 for temporarily storing data during the arithmetic processing. The interface (I/O) 23 converts signals from external sensors (e.g. representing the coolant temperature, crank angle pulses, the signals Ne from the engine speed sensor 7 and Acc from the accelerator pedal sensor 9 into forms that can be processed by the CPU 20 and also converts signals from the CPU 20 into forms adapted for driving external actuators or an injector. The I/O 23 is connected with three drive circuits. A throttle actuator drive circuit 24 amplifies an actuator drive signal from the I/O 23, and its output is applied to the throttle valve actuator (motor) 4. The bypass valve drive circuit 25 is for amplifying a bypass air control signal from the I/O 23, and its output is applied to the bypass air control valve 8. An injector drive circuit 26 converts and amplifies an injector control signal from the I/O 23, and its output is applied to the fuel injector valve 2.

This embodiment is explained with reference to a fuel injection type engine. The fail-safe method and system according to the present invention, however, are applicable with equal effect to carburetor type engines. In the case of a carburetor type engine, a solenoid valve for interrupting the fuel path communicated with the main nozzle may be disposed in the fuel path.

In the following, the main routine of engine control in the method and system according to the preferred embodiment of the present invention will be explained with reference to the flowchart of Fig. 3.

With the start of the engine, the program of the main routine for engine control is started. Step 100 initializes the internal circuits of the control circuit 6. Step 101 applies θ_{th}, Acc, Ne and Qa signals to the CPU 20 through the I/O 23. In addition to these signals, the control circuit 6 may be supplied with a cooling water temperature signal, oxygen sensor output, intake manifold pressure, signal crank angle signal, vehicle speed signal, etc., as indicated in Fig. 2, which can be used as parameters for engine control. These other input signals, however, will not be explained any further herein in order to clarify the nature of the present invention. In step 102 the present intake air flow rate and the engine speed are determined. In step 103 the throttle valve control is executed. In this process of throttle valve control, the throttle valve 3 is driven by the actuator 4 in response to the motion of the acceleration pedal 11. This process also includes a fail-safe control in case of sticking of the throttle valve 3. A detailed explanation will be given later with reference to Figs. 4 and 5. The throttle valve control of step 103 is executed at each predetermined time period, say, 10 ms. The fuel injection amount is then controlled in step 104, where the required fuel supply rate is determined on the basis of input signals such as the intake air amount and the engine speed, and the fuel injection period of the injector valve 2 is controlled through the injector drive circuit 26. Step 104 is also executed at each predetermined time period, say, 10 ms. In step 105 the amount of bypass air is controlled. In the processing of the bypass air amount, when the load increases while the engine is idling, the bypass air path is opened or closed by the bypass air control valve 8 to regulate the intake air amount, thereby maintaining the idling engine speed at a set value. This step 105 further includes a fail-safe control in case the throttle valve 3 sticks. A detailed explanation will be given later with reference to Fig. 6. Step 105 is executed at each pretermined time period, say 20 ms. In step 106 the ignition timing control is executed. In this processing, an optimum ignition timing is determined on the basis of an

intake air amount signal, crank angle signal, engine speed signal, water temperature signal, etc., and a (not shown) ignition system is supplied with an ignition timing signal. This step is also executed at each predetermined time period, say, 20 ms. The process of steps 101 - 106 are repeatedly executed.

Fig. 4 shows a detailed flow chart of the throttle valve control executed at step 103 in Fig. 3. First, in step 200 a flag THNG of the throttle valve sticking is checked. If the THNG flag is at "1" level, it indicates that the throttle valve sticks, while the "0" level of the THNG flag indicates normal throttle valve condition. If THNG is "0", the throttle valve opening degree is determined in step 201 on the basis of the accelerator pedal signal Acc and other parameters indicative of the driving conditions. In accordance with the throttle valve opening degree thus determined, the actuator 4 is driven in step 202 through the actuator drive circuit 24, thus driving the throttle valve 3. In step 203 it is detected whether the throttle valve 3 sticks or not. This detection is effected by judging whether the accelerator pedal control signal θ_{thcont} and the output signal θ_{th} of the throttle valve opening degree sensor 5 are in a predetermined relationship with each other. The hatched area in the graph of Fig. 7, for example, represents the normal operation, whereas the other areas represent the condition of sticking of the throttle valve. This judgement is made by whether the difference between the control signal θ_{thcont} and signal θ_{th} lies within a predetermined range of values. Another method of detecting a sticked throttle valve state is by using the accelerator pedal control signal θ_{thcont} and the intake air flow rate signal Qa. The intake air amount per one engine revolution is related to the sectional area of the intake air path per one engine revolution as shown by the solid line in Fig. 8. Further, the sectional area of the intake air path has a predetermined relationship with the throttle valve opening degree, and the opening angle of the throttle valve corresponds to θ_{thcont} under normal conditions. The normal relation between the value of the sectional area determined by θ_{thcont} and the intake air flow rate Qa is represented by the hatched area of Fig. 8,. whereas sticking of the throttle valve corresponds to the other areas. If in step 204 it is decided that the throttle valve sticks, the driving of the throttle valve 3 by the actuator 4 is suspended in step 205. In step 206 "1" is set at the throttle valve sticking flag THNG. In step 207 the fail-safe control explained with reference to Fig. 5 below is executed.

When the fail-safe control against throttle valve sticking is started, step 300 causes the throttle valve opening degree sensor 5 to detect the present throttle valve opening degree θ_{th}, that is, the sticked opening degree θ_S. Step 301 compares the sticked opening degree θ_S with a reference value θ_R. The reference value θ_R may be selected in optimum design fashion depending on the type of the vehicle involved and the displacement of the engine thereof. The value θ_R may be selected, for example, at such a low valve opening degree at 5° to 10° that the engine rotational speed is 1000 to 3000 min^{-1} under unloaded state. If it is decided in step 301 that $\theta_S > \theta_R$(middle or wide valve opening degree), step 302 is executed to set the reference engine speed for fuel cut N_{FC} and the reference engine speed for fuel recovery N_{FR}in accordance with the value of the accelerator pedal signal Acc. Fig. 9 shows the relationship held between the reference engine speeds N_{FC} and N_{FR} and the accelerator pedal signal Acc. The difference between these two reference values is arranged to be a predetermined value, say, a rotational speed of 100 min^{-1} constant, and provides a hysteresis characteristic. Generally, they are desirably set such that $N_{FC} > N_{FR}$. After the reference values N_{FC}, N_{FR} are set, the actual engine speed Ne is compared in step 303 with the reference values N_{FC}, N_{FR}. If $Ne \geqq N_{FC}$, it indicates that the engine speed has exceeded an upper limit, so that fuel supply from the injector valve 2 is stopped by the injector drive circuit 26. If $Ne \leqq N_{FR}$, on the other hand, the engine speed is excessively low as compared with the accelerator pedal signal Acc, and therefore fuel is injected from the injector valve 2 by the injector drive circuit 26. This fail-safe control function enables the engine speed Ne to be regulated within the range between the upper reference value N_{FC} and the lower reference value N_{FR} in accordance with the operation of the accelerator pedal 11 as shown in Fig. 10, thus making it possible to control the vehicle with the accelerator pedal without any case of runaway. Now, in step 304 and flag THNGBA is set to "0". The flag THNGBA is associated with the throttle valve fixing, and is set to "1" when sticking occurs at a low valve opening degree. In such a case, the fail-safe operation is performed during the period of bypass air amount control explained below. If it is decided in step 301 that $\theta_S < \theta_R$, the flag THNGBA is set to "1" in step 305.

Fig. 6 shows a detailed flow chart of the bypass air amount control of step 105 shown in Fig. 3. In step 400 it is decided whether the flag THNGBA is "1" or not. If the flag THNGBA is not "1", it indicates that the throttle valve is not sticked at a low opening degree, and therefore the bypass air flow rate is set in step 401. This is a normal fast-idle control. The set idling engine speed is thus compared with the actual idling engine speed, and if the actual idling engine speed is lower than the set idling engine speed, the opening amount (duty-ratio) of the bypass air control valve 8 is adjusted to control the bypass air, thereby maintaining the set idling engine speed. In step 401 the opening amount of the air control valve 8, is set, and, in step 402 a pulse signal of a duty factor corresponding to the particular opening amount is applied to the bypass air control valve 8 from the bypass valve drive circuit 25. If it is decided in step 400 that the flag THNGBA is "1", in contrast, it indicates the throttle valve sticked at a low opening degree, and therefore the fail-safe function is performed in step 403 with the bypass air control valve 8. In step 403 a bypass air flow rate corresponding to the accelerator pedal signal Acc ist set thereby to determine the opening amount of the bypass air control valve 8. The bypass air flow rate may be set in the manner mentioned below. As shown by the solid line in Fig. 11, values of all the

intake air amounts Θ_{RSTO} corresponding to the accelerator pedal signal Acc are stored in the ROM 21 of the control circuit 6. The actual intake air flow rate Qa is detected by the air flow meter 1 thereby to determine the difference ΔQa between the value in the ROM 21 and the actual value. The air amount equivalent to ΔQa determines the opening amount of the bypass air control valve 8. Step 402 causes the bypass valve drive circuit 25 to drive the bypass air control valve 8 by a signal of a duty factor corresponding to the determined valve opening amount. By controlling the bypass air control valve 8 this way, the vehicle is driven safely with the accelerator pedal 11 even if the throttle valve 3 sticks at a low opening degree with a small intake air flow rate.

In the above-mentioned embodiment, it is assumed that for a throttle valve 3 sticking at a small throttle valve angle air bypass control is made, and for a throttle valve 3 sticking at a large throttle valve angle fuel cut (recovery) control is carried out.

However, the according to another embodiment, three ranges of the angle of the sticked throttle valve 3 may be applied, such as small, medium and large throttle valve opening angles. At small throttle valve angles, the bypass air control is made, whereas the fuel cut control is made, at wide angles, and at medium throttle valve angles, both controls are made.

Claims

1. A fail-safe method for the operation of internal combustion automotive engines comprising fuel supply means supplying fuel to the engine and a throttle valve provided in the air intake path of the engine and driven by an actuator for controlling the intake air amount of the engine,

characterized by

- detecting the amount of depression of the accelerator pedal,
- controlling the throttle valve on the basis of the detected amount of depression of the accelerator pedal,
- detecting of sticking of the throttle valve, and
- in response to the detection of sticking of the throttle valve
- controlling the fuel supply rate from the fuel supply means in accordance with the amount of depression of the acceleration pedal and/or
- controlling the intake air amount via a bypass air amount introduced by means of an auxiliary air path bypassing the throttle valve in accordance with the amount of depression of the acceleration pedal.

2. The method according to claim 1, characterized in that in response to the detection of sticking of the throttle valve the fuel supply rate is controlled in accordance with the amount of depression of the accelerator pedal if the throttle valve is sticked at a middle or high opening degree, and the bypass air amount is controlled if the throttle valve is sticked at a low opening degree.

3. The method according to claim 1 or 2, characterized in that

- the opening degree of the throttle valve is detected, and
- sticking of the throttle valve is detected when the difference between the detected opening degree of the throttle valve and the signal for controlling the throttle valve exceeds a predetermined value.

4. The method according to one of claims 1 to 3, characterized in that in response to the detection of sticking of the throttle valve

- an upper engine speed reference value N_{FC} and a lower engine speed reference value N_{FR} corresponding to the amount of depression of the accelerator pedal are set,
- the actual engine rotational speed Ne is detected,
- the reference values N_{FC} and N_{FR} are compared with the detector actual engine speed Ne,
- the fuel supply from the fuel supply means is stopped when the actual engine speed Ne is larger than or equal to the upper engine speed reference value N_{FC}

and

- the fuel supply means are controlled to supply fuel when the actual engine speed Ne is smaller than or equal to the lower engine speed reference value N_{FR}.

5. The method according to claim 4, characterized in that the engine speed reference values N_{FC} and N_{FR} are set such that the difference therebetween is fixed and proportional to the amount of depression of the accelerator pedal.

6. The method according to one of claims 1 to 5, characterized in that for engines comprising a fuel injection system the required fuel supply rate is determined on the basis of the output of an air-flow meter, and the fuel injector(s) representing the fuel supply means are controlled in accordance with the required fuel supply rate, and the bypass air amount is controlled by means of a bypass air control valve by changing the duty ratio thereof.

7. A fail-safe system for internal combustion automotive engines in which a throttle valve (3) for controlling the intake air path of the engine is provided which is driven by an actuator (4), particularly for carrying out the method according to one of claims 1 to 6, comprising

- fuel supply means (2) for supplying fuel to the engine (3),
- means (9) for detecting the amount of depression of the accelerator pedal (11),
- signal producing means (60 for producing an output signal for controlling the throttle valve (3) on the basis of the detector amount of depression of the accelerator pedal (11),
- sticking detection means (203) for detecting that the throttle valve (3) is sticked,

and

- fuel supply rate control means (104) for

controlling the fuel supply rate from the fuel supply means (2) in accordance with the amount of depression of the accelerator pedal (11) in response to the detection of sticking of the throttle valve (3).

8. The fail-safe system according to claim 7, further comprising means (5) for detecting the opening degree of the throttle valve (3), said sticking detection means (203) including difference detection means for detecting the difference between the output signal of the signal producing means (6) and the detected opening degree of the throttle valve (3) and producing a signal indicating sticking of the throttle valve (3) when the difference between the amount of said output signal and the detected opening degree of the throttle valve (3) exceeds a predetermined value.

9. The fail-safe system according to claim 7 or 8, further comprising engine speed reference value setting means for setting an upper engine speed reference value N_{FC} and a lower engine speed reference value N_{FR} corresponding to the amount of depression of the accelerator pedal (11) in response to a signal indicating sticking of the throttle valve (3), means (7) for detecting the actual engine speed Ne, and means for comparing the reference values N_{FC}, N_{FR} with the detected actual engine speed Ne and producing the result of comparison, the fuel supply rate control means (104) stopping the fuel supply from the fuel supply means (2) when the result of comparison shows that the actual engine speed Ne is larger than or equal to the upper engine speed reference value $N_{FC}$and causes the fuel supply means (2) to supply fuel when the actual engine speed Ne is smaller than or equal or the lower engine speed reference value N_{FR}.

10. The fail-safe system according to claim 9, wherein the reference values N_{FC} and N_{FR} represent different engine speeds with the difference therebetween fixed and proportional to the amount of depression of the accelerator pedal (11).

11. The fail-safe system according to one of claims 7 to 10, further comprising an auxiliary air path bypassing the throttle valve (3), a bypass air control valve (8) provided therein for controlling the auxiliary air path, means for setting the bypass air amount corresponding to the amount of depression of the accelerator pedal (11), means for comparing the opening degree of the sticked throttle valve (3) with a predetermined throttle valve opening degree reference value Θ_R in response to a signal indicating the fixing of the throttle valve (3), and means for controlling the bypass air control valve (8) in accordance with the set value of the bypass air amount setting means when the opening degree of the sticked throttle valve (3) is lower than the throttle valve opening reference value Θ_R, the fuel supply rate control means (104) controlling the fuel supply means (2) when the opening degree of the sticked throttle valve (3) is higher than the throttle valve opening reference value Θ_R.

12. A fail-safe system according to one of claims 7 to 11 for engine comprising a fuel injection system wherein the required fuel flow rate is determined on the basis of the output of an intake air-flow meter and one or more fuel injectors (2) representing the fuel supply means are controlled in accordance with the required fuel supply rate, the bypass air control valve (8) controls the bypass air amount in accordance with a change in the duty ratio thereof.

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FIG. 1

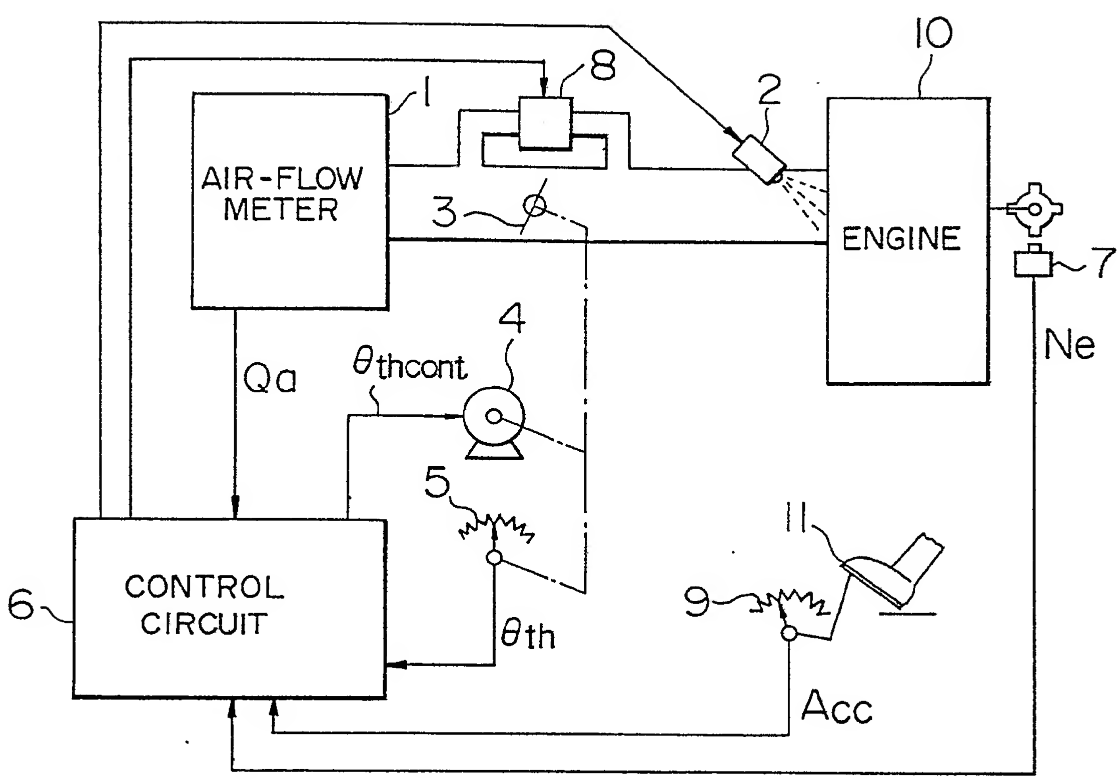

FIG. 2

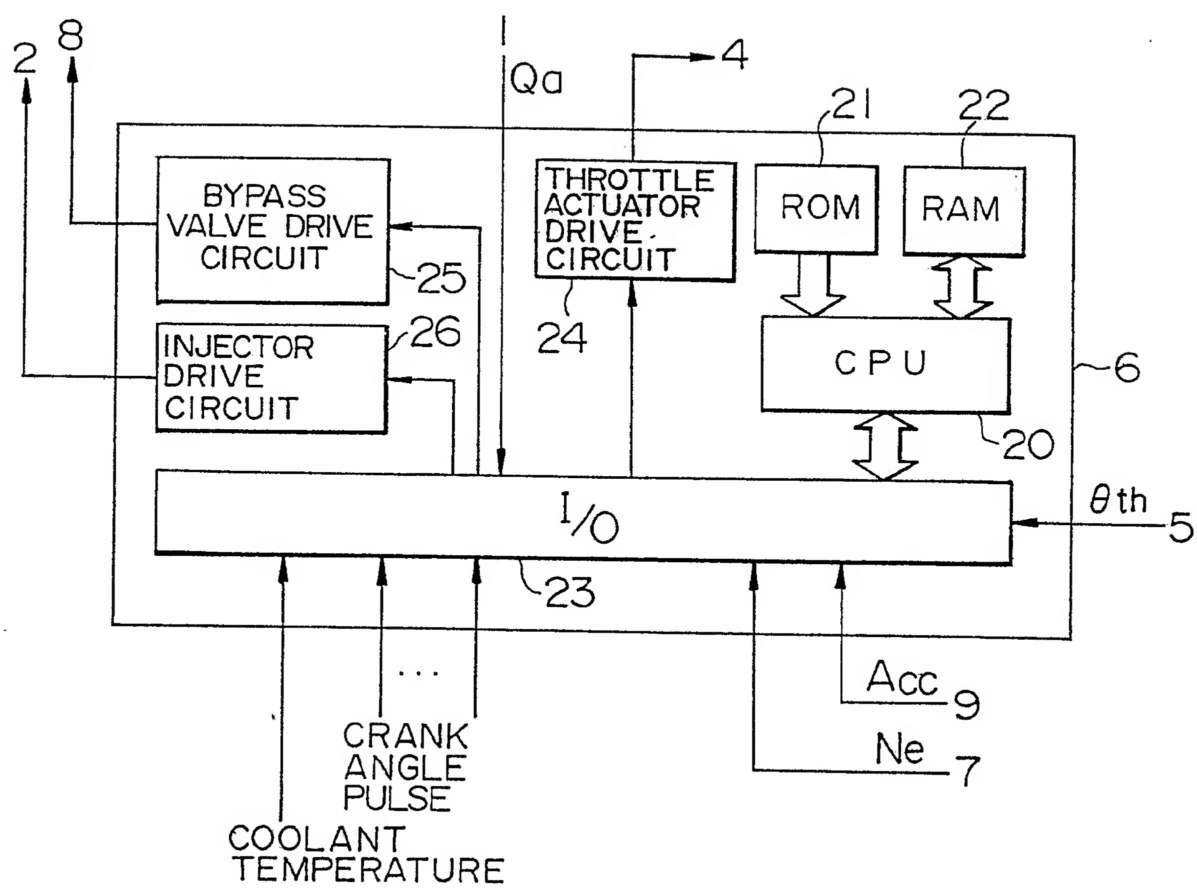
2
8
Qa
4
21
22
BYPASS VALVE DRIVE CIRCUIT
25
THROTTLE ACTUATOR DRIVE CIRCUIT
24
ROM
RAM
INJECTOR DRIVE CIRCUIT
26
CPU
6
20
I/O
θth
5
23
Acc
9
Ne
7
CRANK ANGLE PULSE
COOLANT TEMPERATURE

FIG. 3

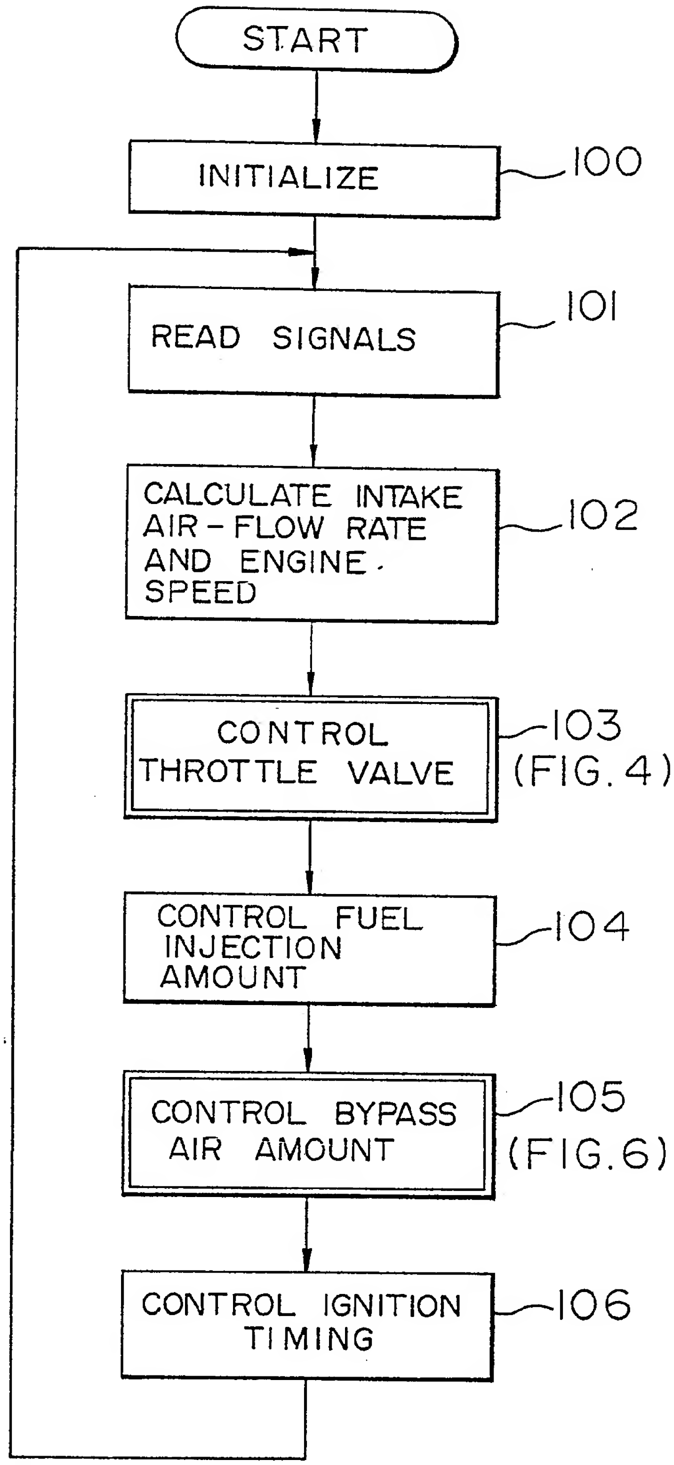
START
INITIALIZE
100
READ SIGNALS
101
CALCULATE INTAKE AIR-FLOW RATE AND ENGINE SPEED
102
CONTROL THROTTLE VALVE
103
(FIG. 4)
CONTROL FUEL INJECTION AMOUNT
104
CONTROL BYPASS AIR AMOUNT
105
(FIG. 6)
CONTROL IGNITION TIMING
106

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FIG. 4

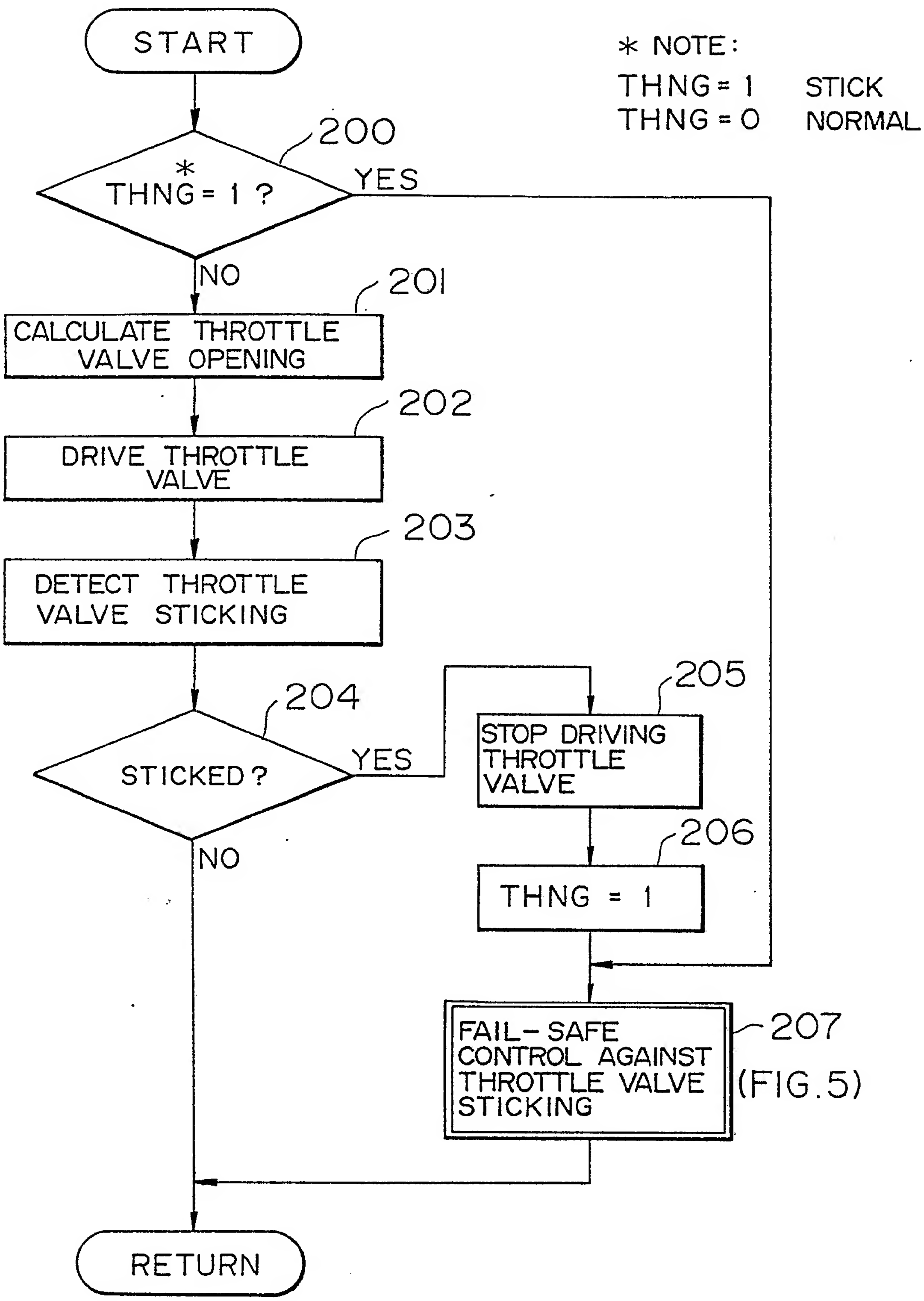
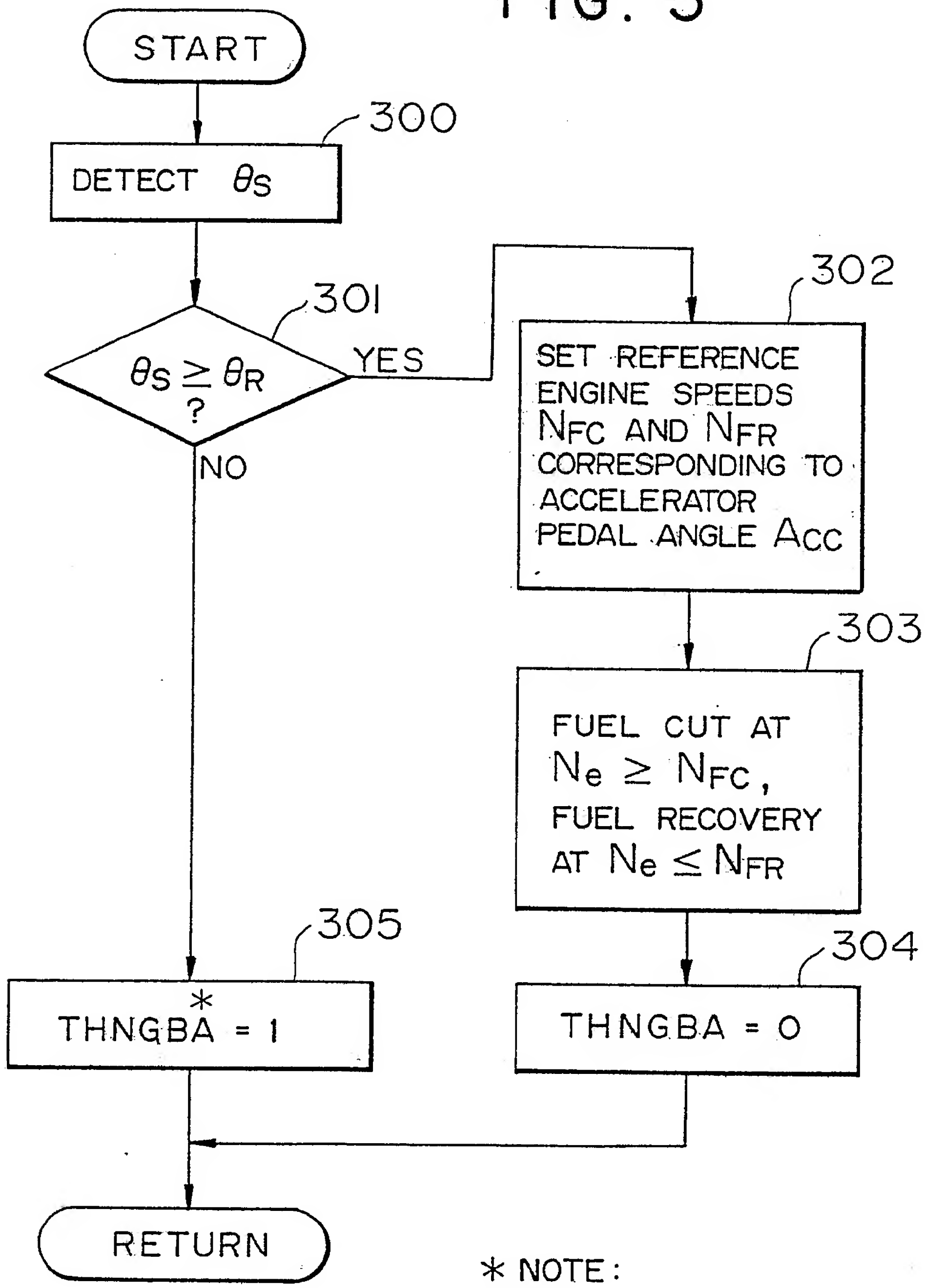


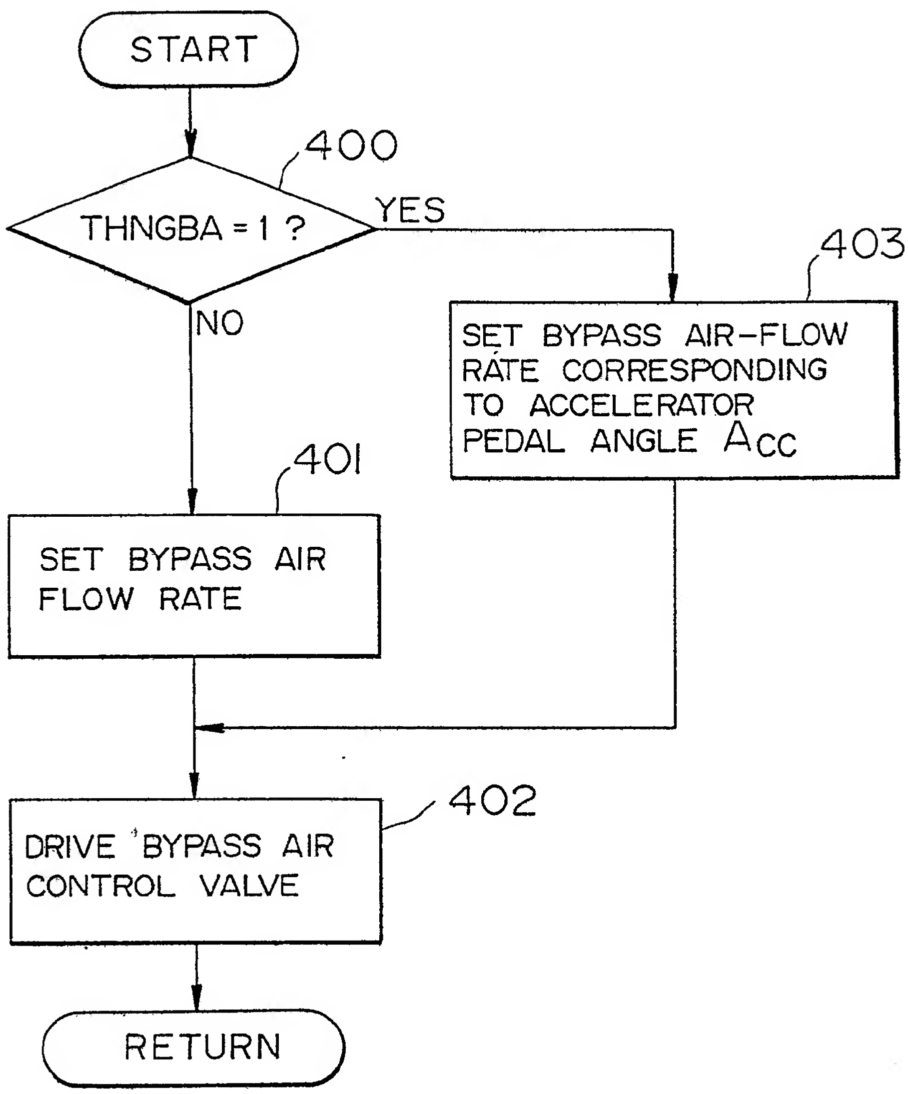
FIG. 5



* NOTE:

THNGBA = 1 NEED FAIL-SAFE
THNGBA = 0 NO FAIL-SAFE

FIG. 6


START
400
THNGBA = 1 ?
YES
NO
403
SET BYPASS AIR-FLOW RATE CORRESPONDING TO ACCELERATOR PEDAL ANGLE Acc
401
SET BYPASS AIR FLOW RATE
402
DRIVE BYPASS AIR CONTROL VALVE
RETURN

0276003

FIG. 7

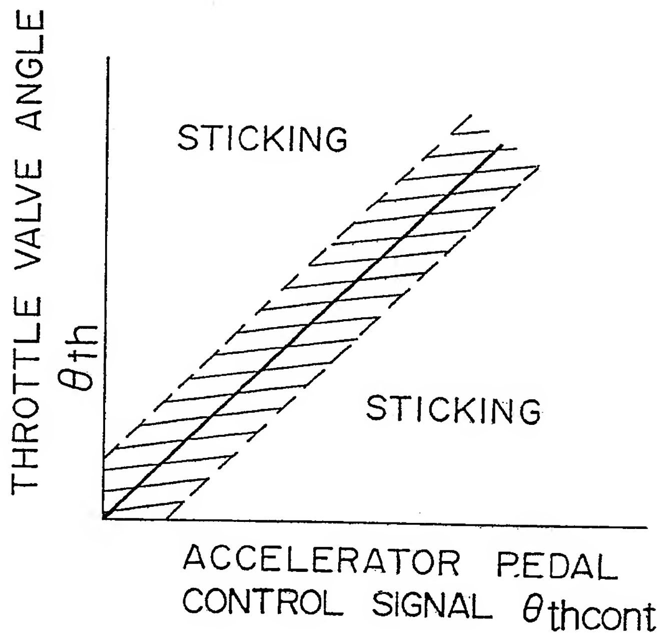
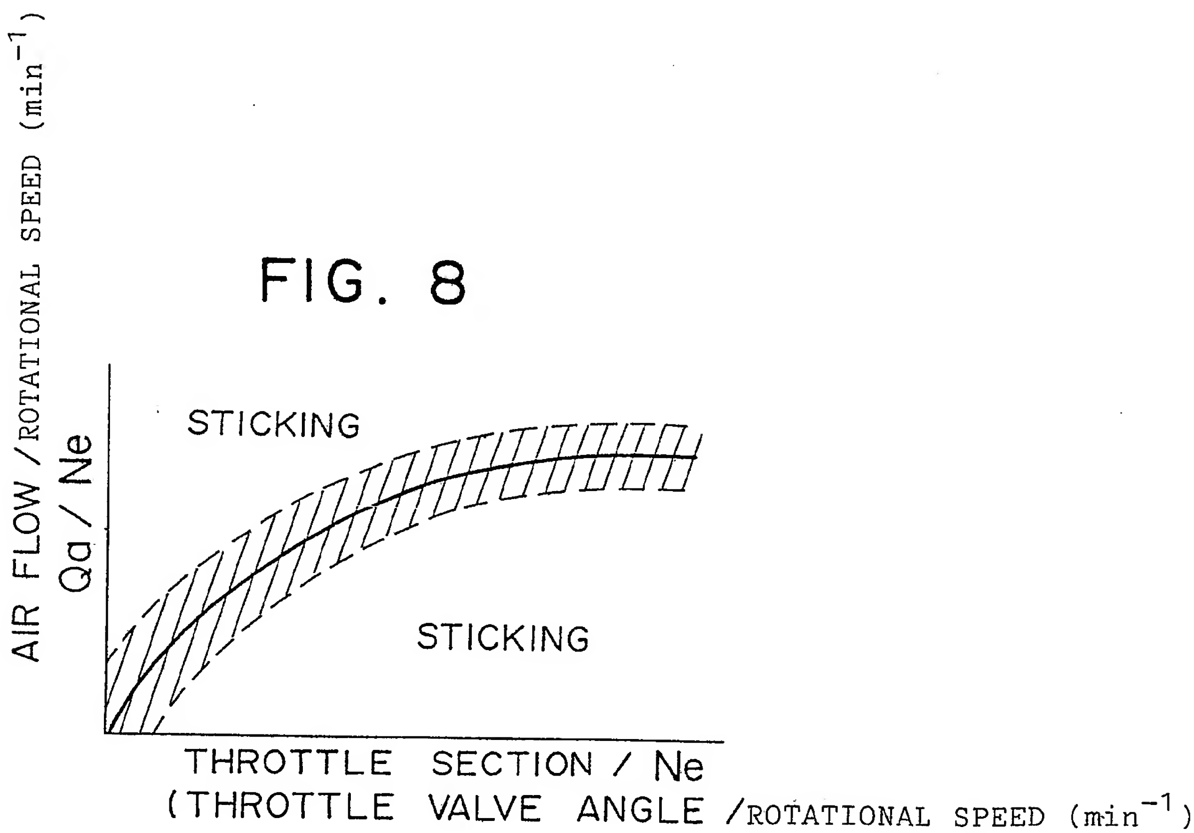


FIG. 8



0276003

FIG. 9

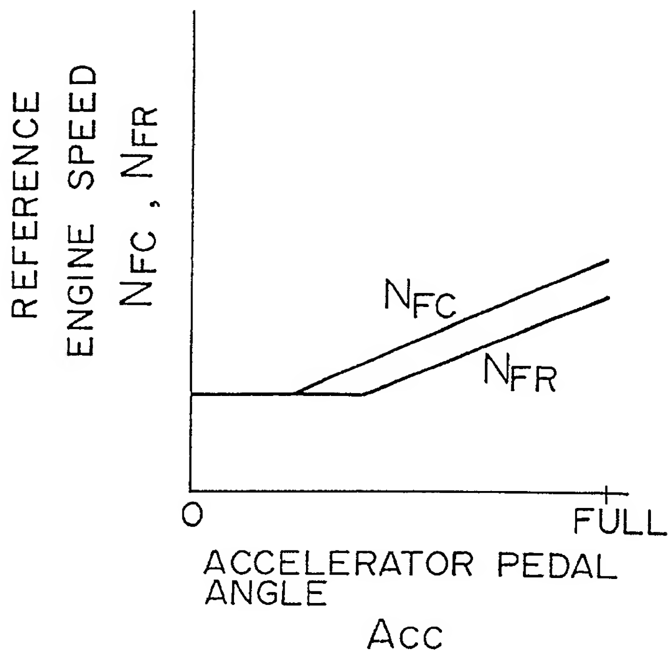


FIG. 11

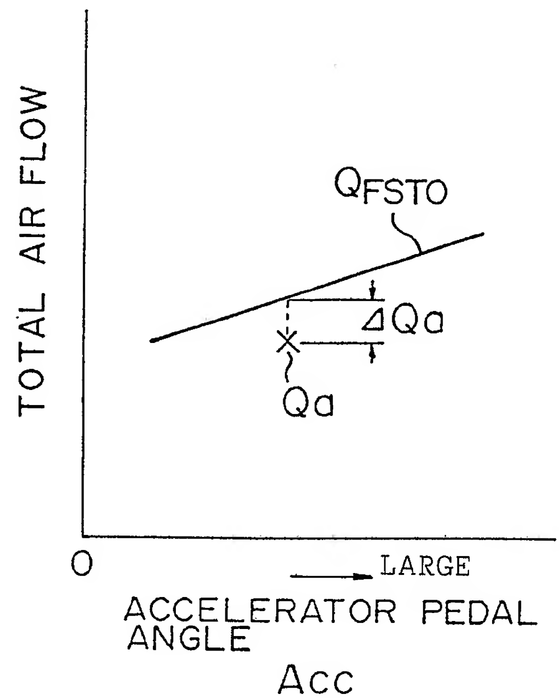


FIG. 10